United States Patent [19]

Takei et al.

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[45] **Date of Patent: Apr. 1, 1986**

[54] **HOT GAS RECIPROCATING APPARATUS AND CONVECTOR HEATER**

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[73] Assignee: **Sanden Corporation**, Gunma, Japan

[21] Appl. No.: **687,170**

[22] Filed: **Dec. 28, 1984**

[30] **Foreign Application Priority Data**

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Dec. 28, 1983 [JP] Japan 58-249970
Dec. 28, 1983 [JP] Japan 58-249971

[51] **Int. Cl.**^{4} **F02G 1/04**
[52] **U.S. Cl.** **60/517**; 60/526
[58] **Field of Search** 60/517, 524, 526

[56] **References Cited**

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Primary Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Banner, Birch, McKie & Beckett

[57] **ABSTRACT**

A hot gas reciprocating apparatus is disclosed in which a displacer piston and power piston operate within a cylinder due to flow of medium gas which is heated and cooled through a heater and a cooler. The cylinder is divided into a upper chamber and lower chamber by the displacer piston, and the lower chamber is defined between displacer piston and power piston. The upper chamber and lower chamber are connected with one another through the heater, a regenerator and the cooler, whereby the medium gas flows into the lower chamber from the upper chamber or vice versa. The heater, which receives heat from heat sources, projects radially from the cylinder to extend over the heat source; and the cooler projects radially from the cylinder on an opposite side from which heater extends. The heater and cooler are axially spaced from one another along the axis of the cylinder. Thus, a high temperature difference between the heater and cooler is obtained to accomplish highly efficient operation of the hot gas reciprocating apparatus.

7 Claims, 9 Drawing Figures

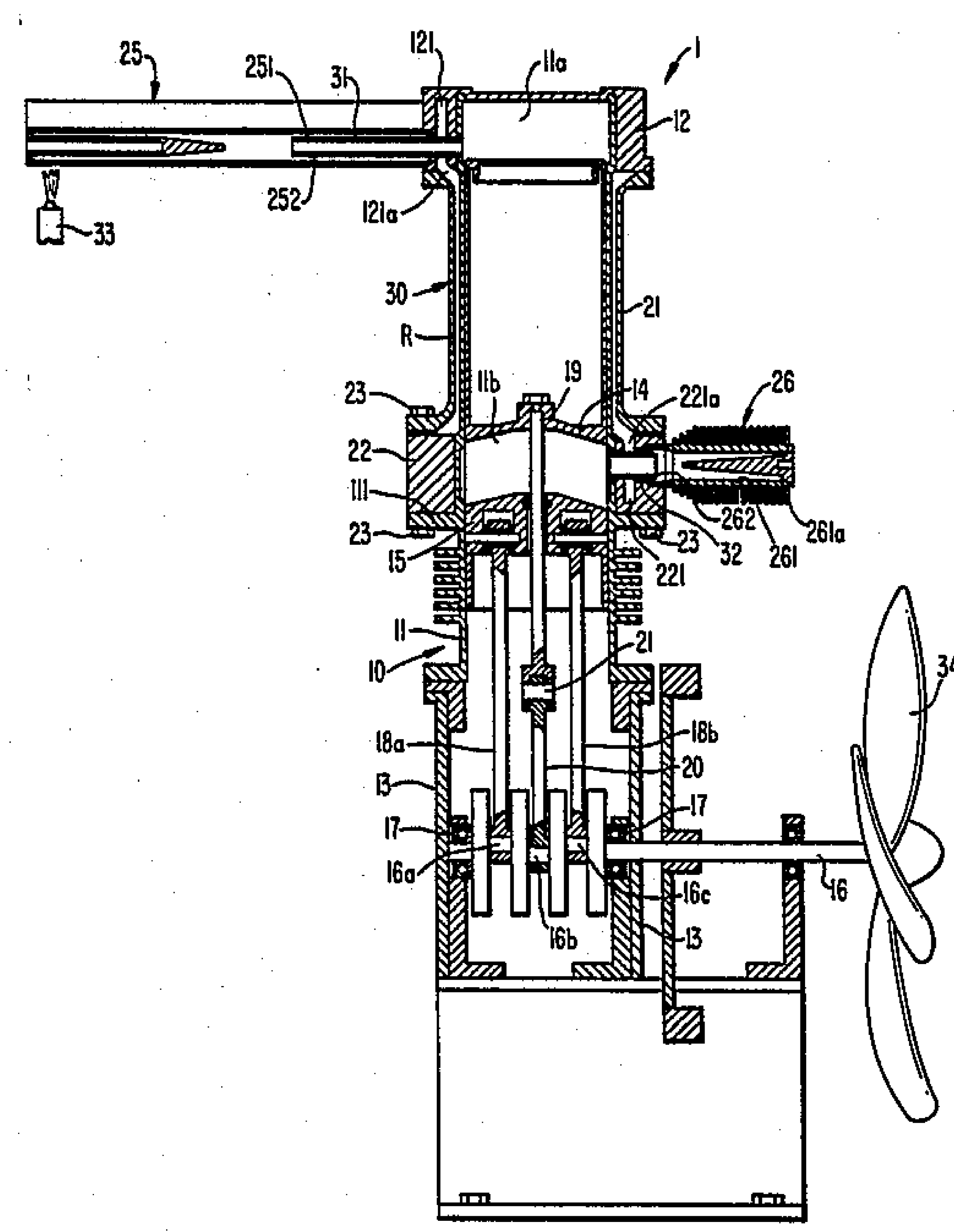
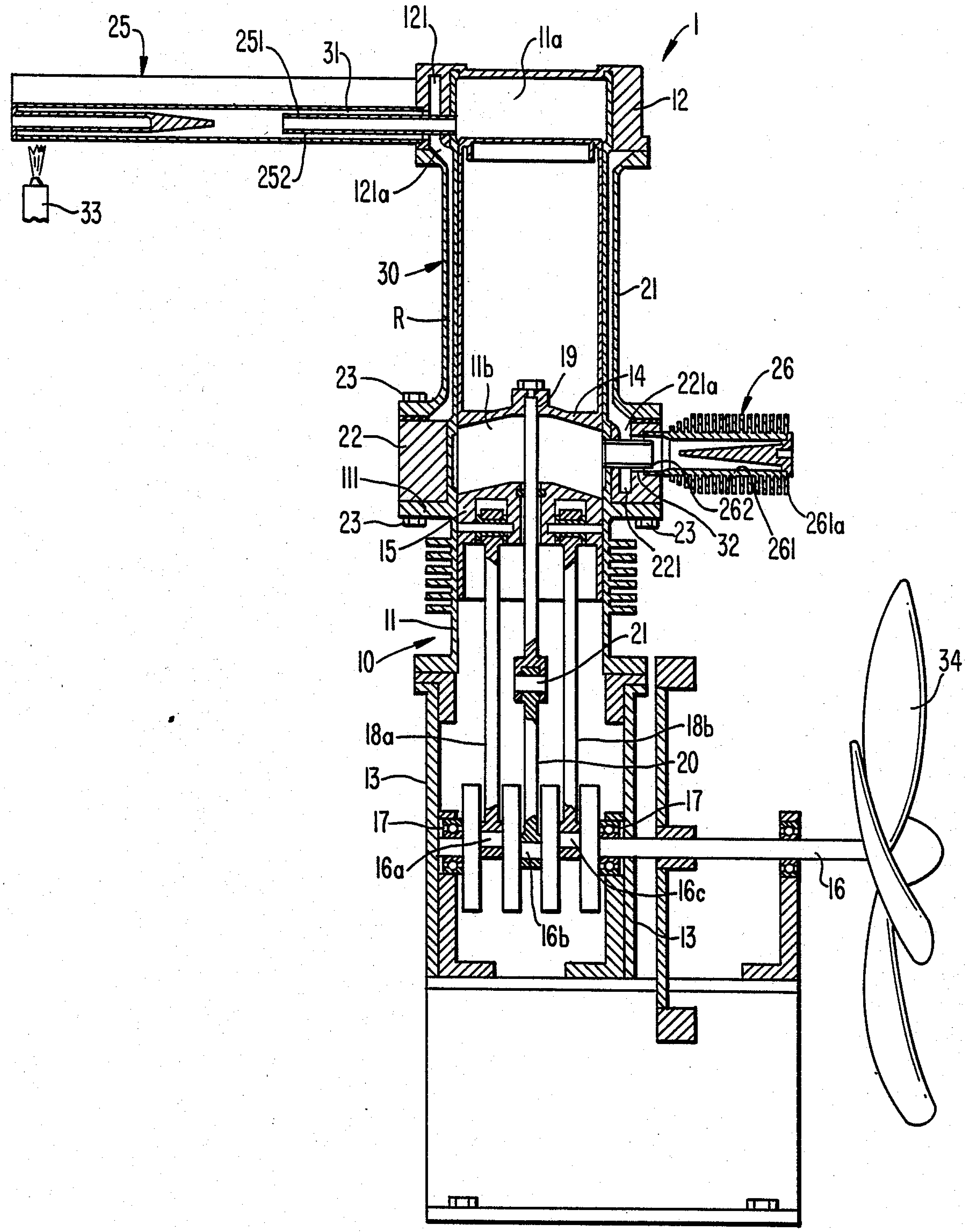


FIG. 1.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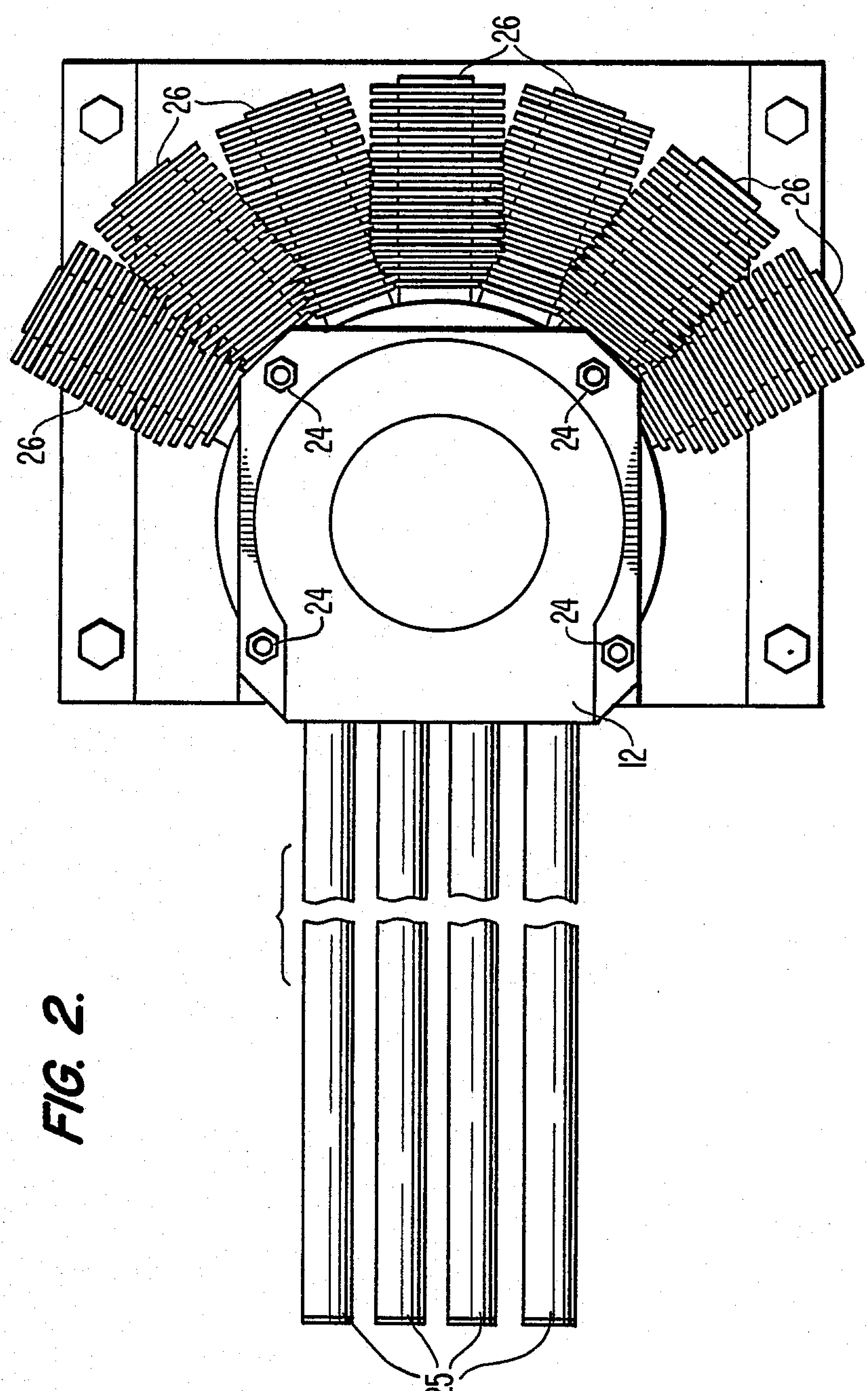

FIG. 2.

FIG. 3.

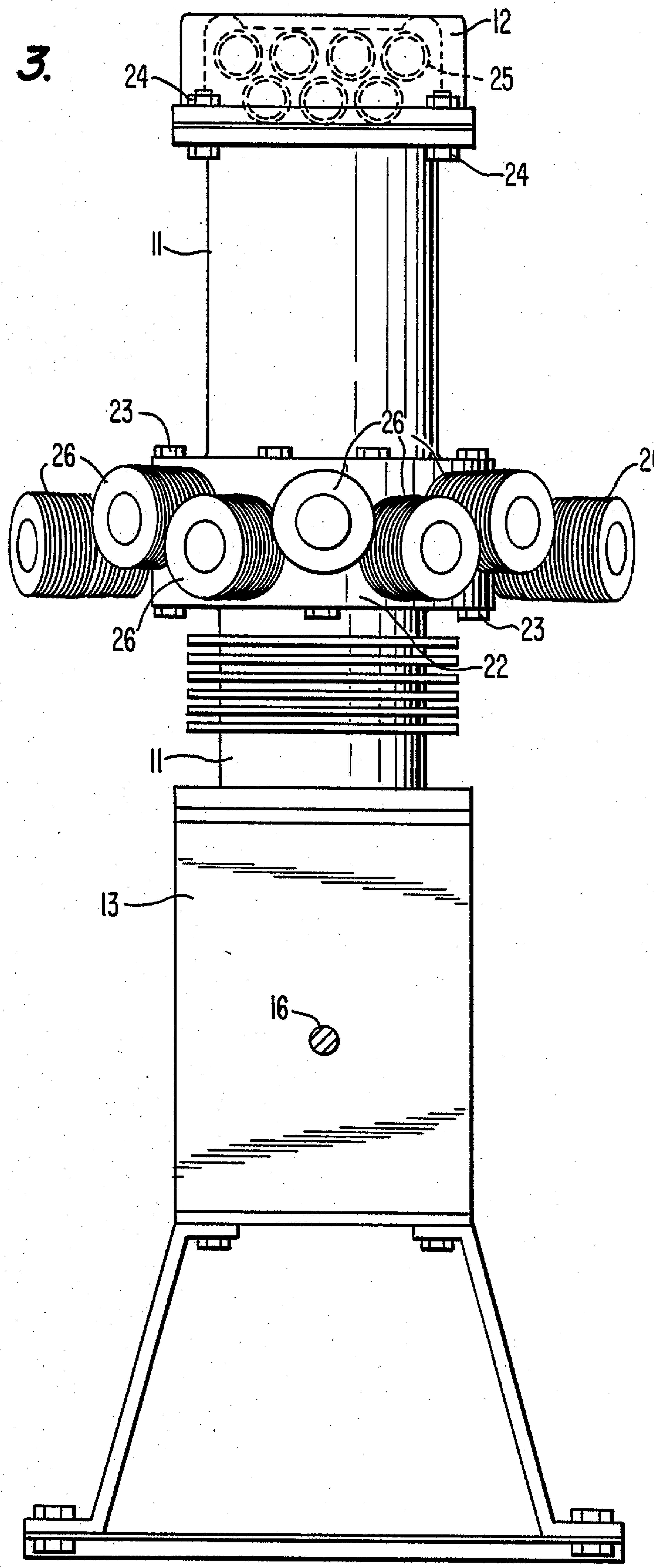

FIG. 4.

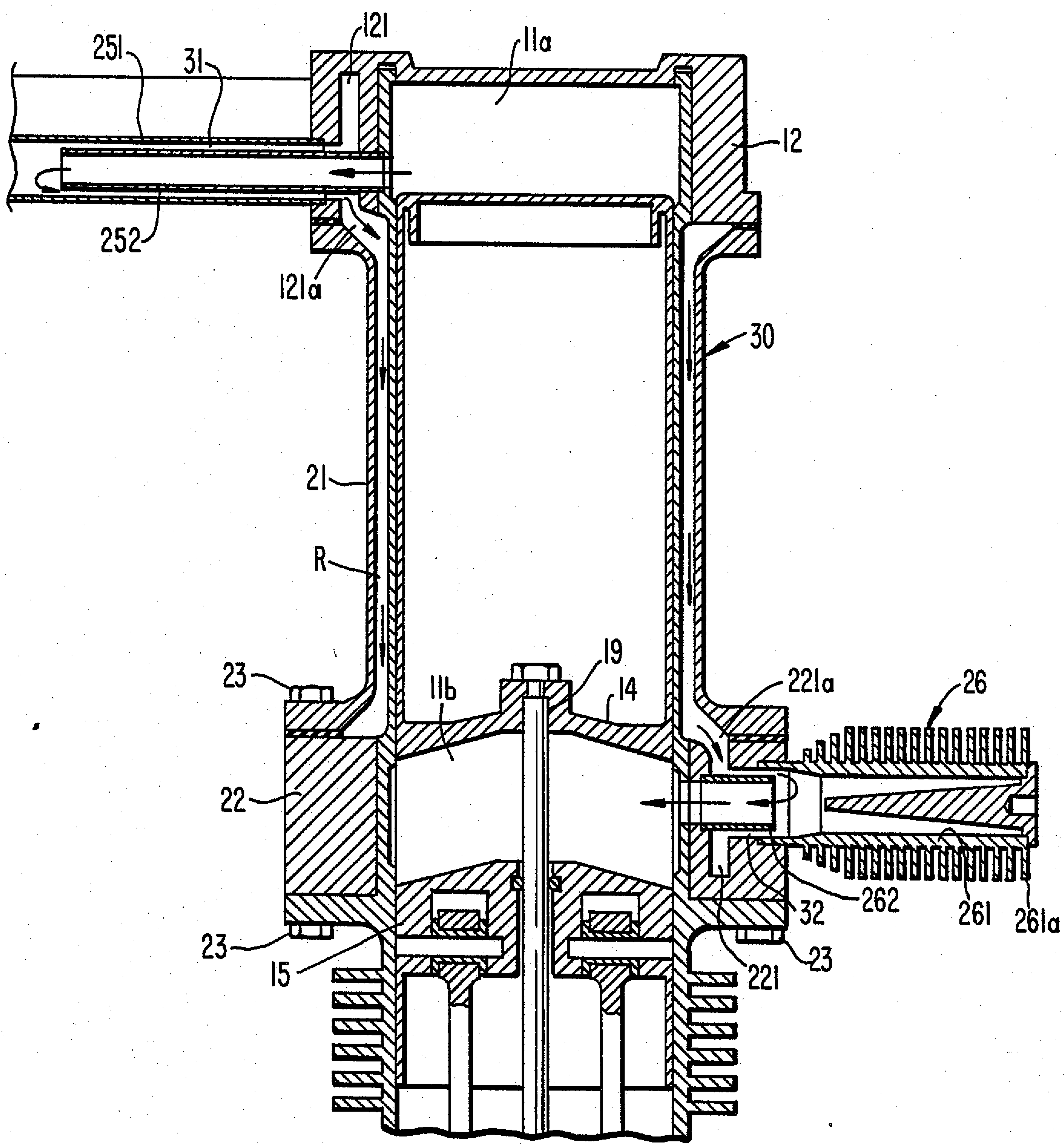
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FIG. 5.

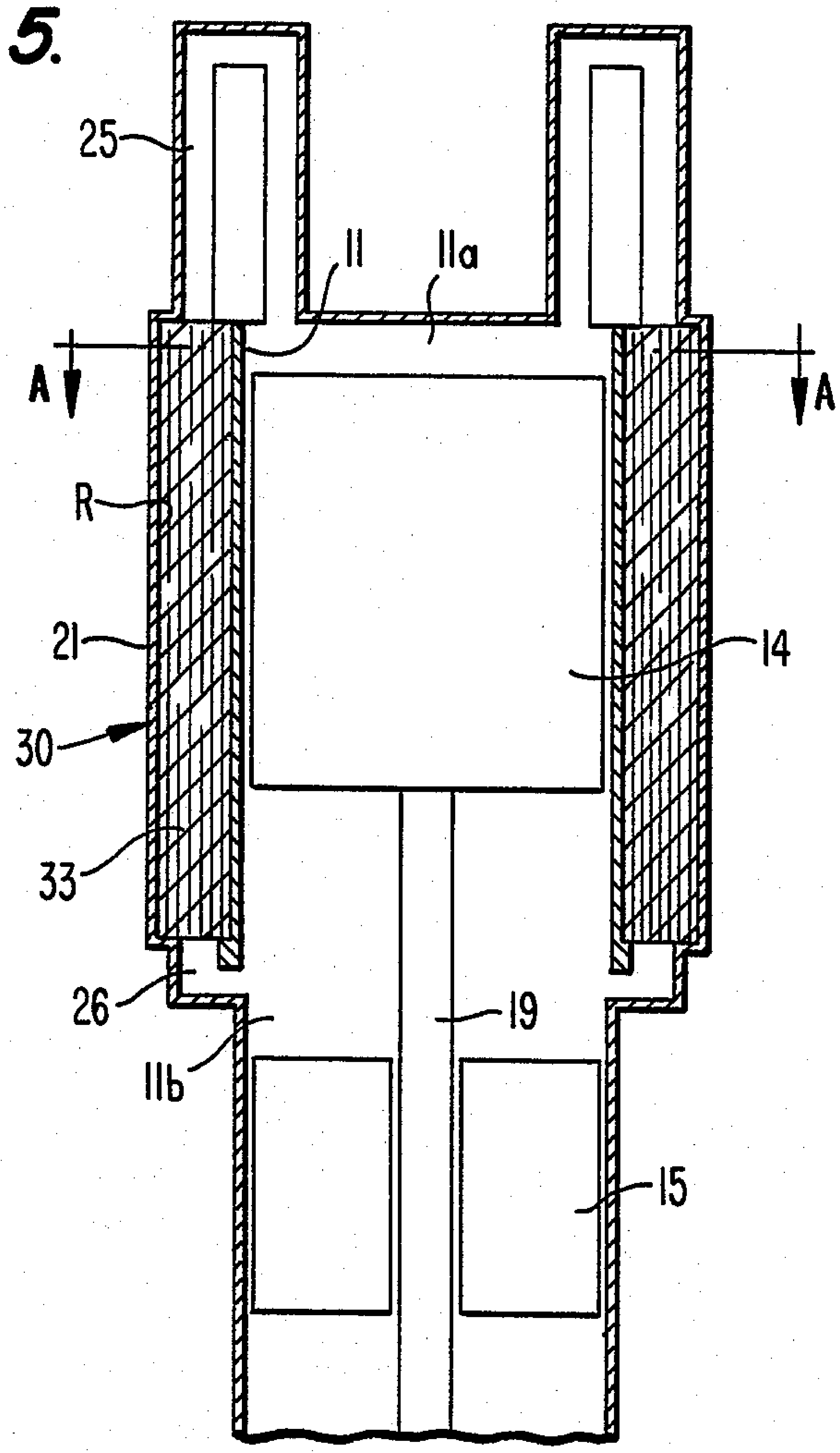


FIG. 6.

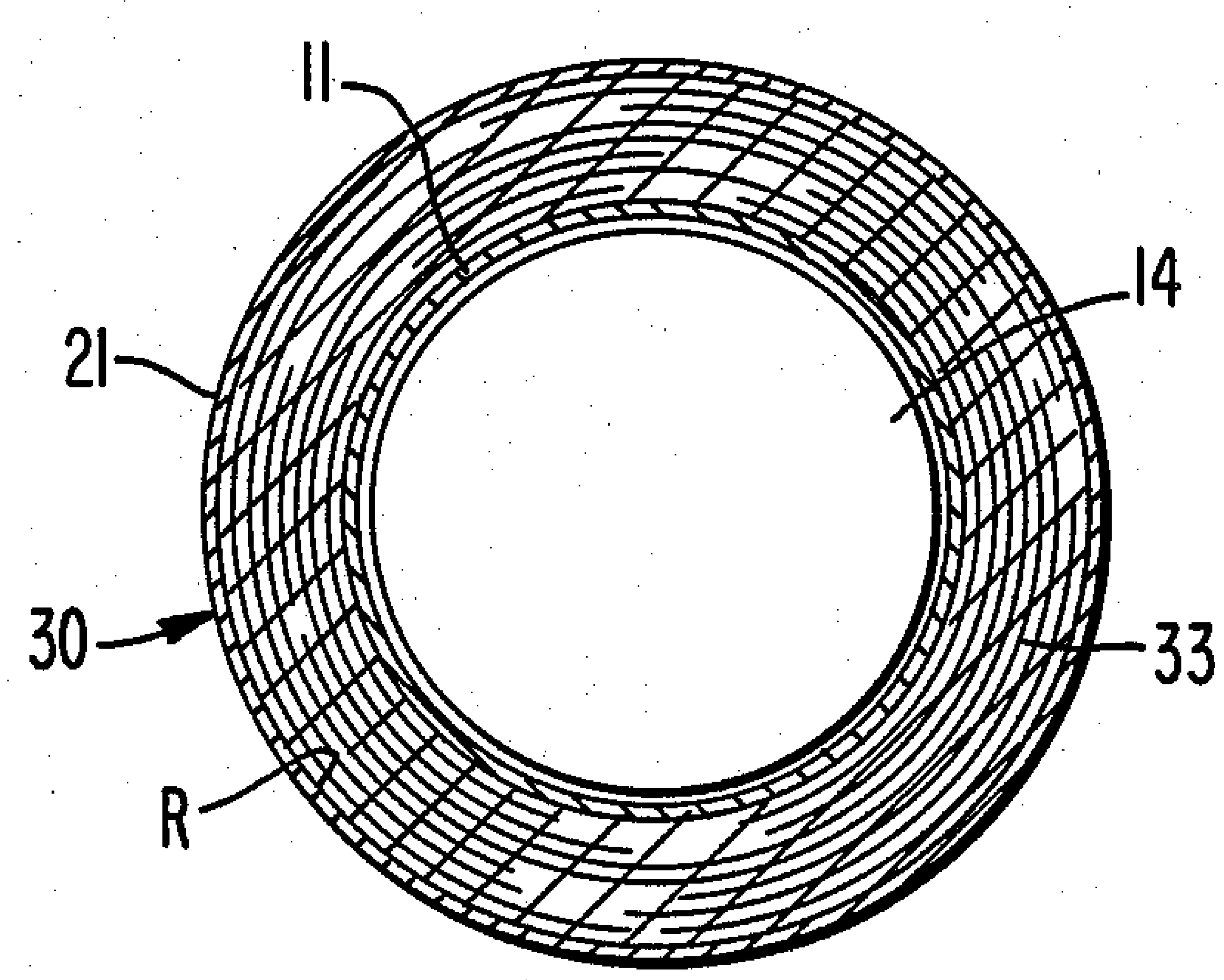


FIG. 7

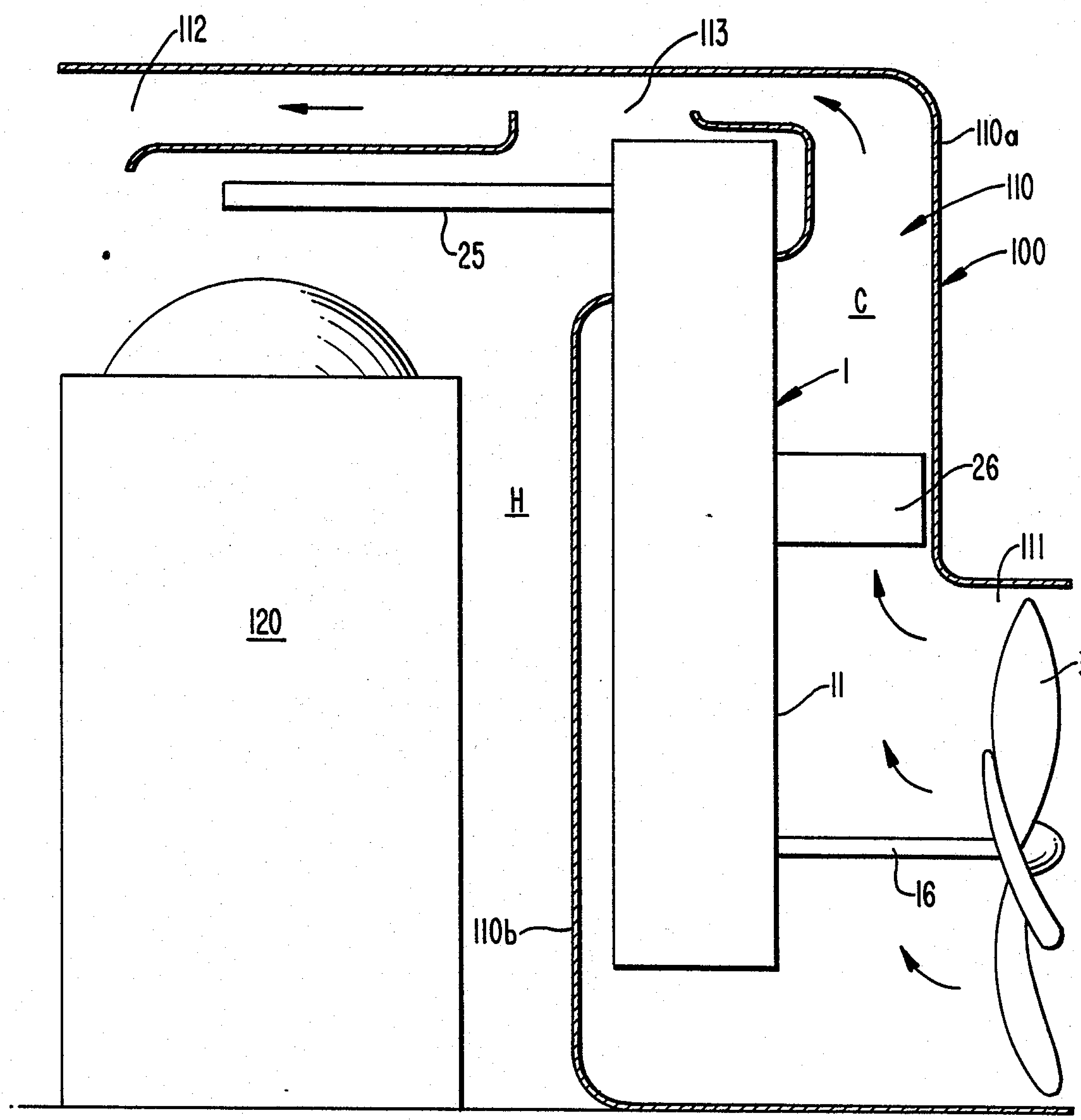
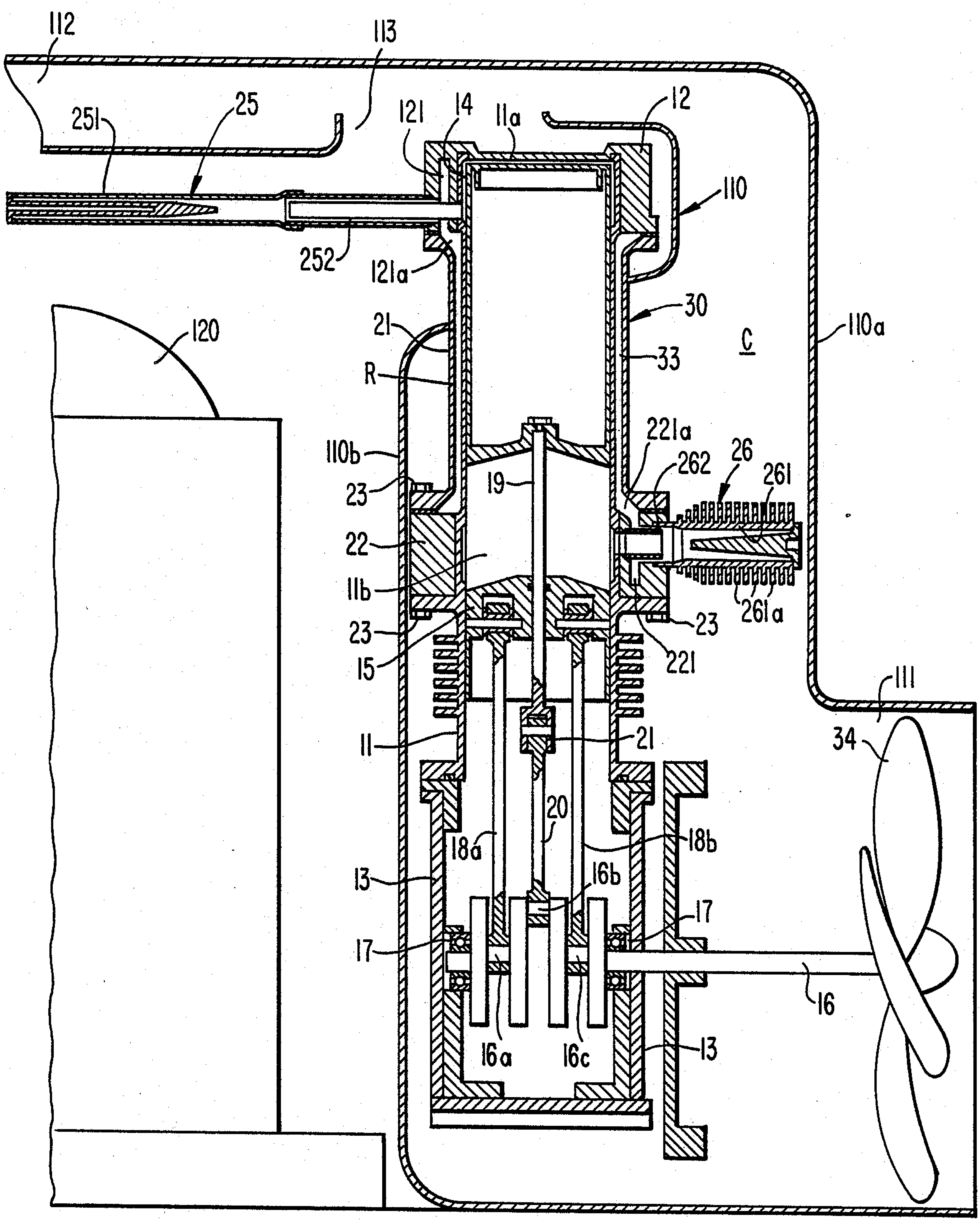


FIG. 8.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262
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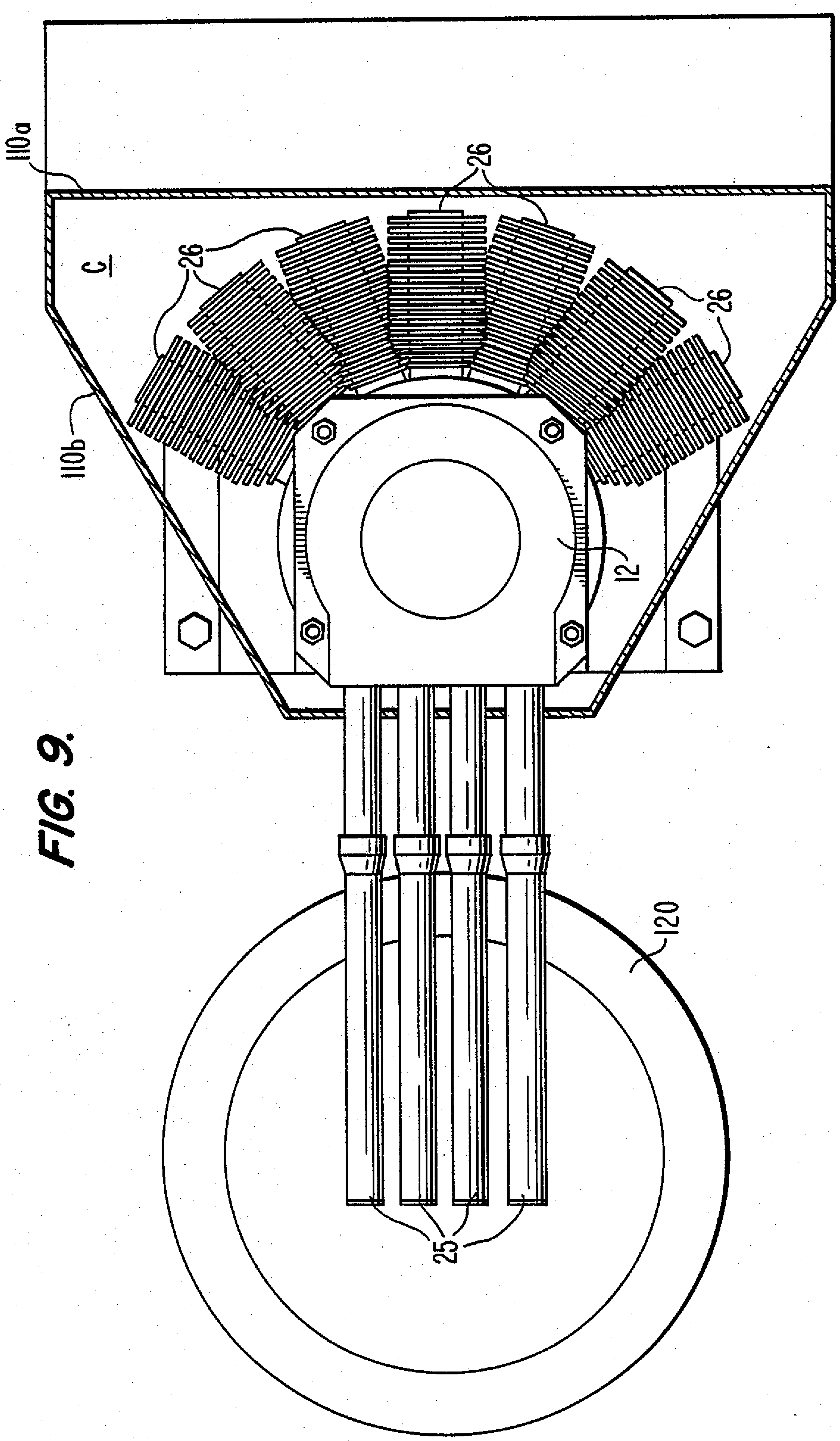

FIG. 9.

HOT GAS RECIPROCATING APPARATUS AND CONVECTOR HEATER

TECHNICAL FIELD

This invention generally relates to a hot gas reciprocating apparatus, and more particularly, to a simplified Stirling cycle type engine in which heat from an external source is converted to useful mechanical energy.

BACKGROUND OF THE INVENTION

Stirling cycle type engines are well known in the prior art. A Stirling cycle machine is a device which operates on a regenerative thermodynamic cycle, with cyclic compression and expansion of the working fluid at different temperature levels, wherein the flow of the fluid is controlled by volume changes so that there is a net conversion of heat to work or vice versa. In a typical Stirling cycle engine, operating as a prime mover, heat is supplied to the working fluid at some high temperature Th, when the fluid is in a hot chamber. Part of the heat is converted to work when working fluid, due to the absorbed heat, expands and thereby pushes on a piston, which is coupled to a crank shaft that imparts rotary motion. The working fluid is then displaced by a displacer through a regenerator and forced into a cold chamber, which is at some lower temperature Tl. Thereafter, the working fluid is forced out of the cold chamber by the displacer through the regenerator into the hot chamber; and, as it passes through the regenerator reabsorbs some of the heat previously deposited there. In the hot chamber it again absorbs heat and the cycle of operation repeats itself.

In a Stirling cycle engine operating as a prime mover, the working fluid expansion takes place in the hot chamber, while most of the compression takes place in the cold chamber. As is appreciated by those familar with the art, when the Stirling cycle is used in a hot-gas engine, the working fluid expansion occurs in the hot chamber while the compression of the working fluid, during which heat is rejected, takes place in the cold chamber. In either type machine, the working fluid is shifted between the two chambers through a regenerator by means of a displacer. The motion of the displacer is generally synchronized with the piston motion by means of mechanical linkages which add to the complexity of the machine.

The theoretical maximum efficiency of a hot-gas engine is determined by the following formula:

$$(Th-Tl)/Th$$

wherein Th denotes the absolute temperature prevailing on the hot side of the engine and Tl the absolute temperature prevailing on the cold side of the engine. Therefore, it is important for satisfactory efficiency to maintain the temperature on the hot side of the engine as high as possible and on the cold side of the engine as low as possible.

SUMMARY OF THE INVENTION

It is a primary object of this invention to provide an improved hot gas reciprocating apparatus which achieves high efficiency.

It is another object of this invention to provide a hot gas reciprocating apparatus which is simple in construction and easy to manufacture.

It is another object of this invention to provide a new heating device which utilize the compact hot gas reciprocating apparatus.

A hot gas reciprocating apparatus according to this invention includes a power piston and a displacer both of which are slidably carried within a cylinder. The movable displacer divides an internal space of the cylinder into two chambers. These two chambers are connected to one another through a cooler, a regenerator and a heater. The cooler and heater each comprises a plurality of pole shaped members which include an outer tube element and inner tube element that define a double passage-way. The cooler and heater extend from an outer peripheral surface of the cylinder in opposite directions, axially offset from one another, and parallel to one another.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical sectional view of a hot gas reciprocating apparatus according to one embodiment of this invention.

FIG. **2** is a top plan view of the hot gas reciprocating apparatus in FIG. **1**.

FIG. **3** is a side view of the hot gas reciprocating apparatus in FIG. **1**.

FIG. **4** is a partial cross-sectional view of the hot gas reciprocating apparatus, illustrating the flow of working fluid.

FIG. **5** is a schematic cross-sectional view of another embodiment of hot gas reciprocating apparatus.

FIG. **6** is a cross-sectional view taken along line A—A in FIG. **5**.

FIG. **7** is a diagrammatic view of a heating device which utilizes the hot gas reciprocating apparatus.

FIG. **8** is a vertical sectional view of a convector heater utilizing a hot gas reciprocating apparatus according to the first embodiment of this invention.

FIG. **9** is a top plan view of the heater in FIG. **8**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a hot gas reciprocating apparatus according to one embodiment of this invention is shown. The apparatus **1** comprises an annular housing **10** having a cylinder **11**, a cylinder cap **12** disposed on one end portion of cylinder **11** to close the opening in the one end portion, and a crank case **13**.

A displacer piston **14** is slidably carried within cylinder **11** and divides the cylinder into two chambers. A power piston **15** is also slidably carried within cylinder **11** and placed in the lower portion of cylinder **11**. A top surface of power piston **15** faces the bottom surface of displacer piston **14**. An upper chamber of cylinder **11** functions as a heat chamber **11*a*** and a space defined between displacer piston **14** and power piston **15** functions as a cold chamber **11*b***. Both pistons **14**, **15** are linked to a crankshaft **15** which is rotatably supported in crank case **13** through bearings **17**. Crankshaft **16** has three cranks **16*a*, 16*b*, 16*c*** extending from it. The two outside cranks **16*a*** and **16*c*** extend from crankshaft **16** at the same angle and are linked to power piston **15** by two parallel connector rods **18*a*, 18*b***. Displacer piston **14** is actuated by middle crank **16*b***, which is offset by a certain angle from the other two cranks **16*a*, 16*c***. Displacer piston **14** is coupled to middle crank **16*b*** through a rod **19** which is linked by a linkage **21** to a connector rod **20** fastened on crank **16*b***.

An annular cylindrical member **21** is disposed around an outer peripheral surface of cylinder **11**. A gap between cylinder **11** and cylindrical member **21** defines a regenerating space R, i.e., a regenerator **30** is formed between the outer peripheral surface of cylinder **11** and the inner peripheral surface of cylindrical member **21**. Cylindrical member **21** is placed around the upper portion of cylinder **11** and fixed on cylinder **11** through a connecting member **22** by a plurality of bolts **23**. Connecting member **22** is supported on a radial flange portion **111** projecting radially from the outer peripheral surface of cylinder **11**; and the lower end portion of cylindrical member **21** is placed on, and fastened to, the upper end surface of connecting member **22**. The upper end surface of cylindrical member **21** fits against the bottom end surface of cylinder cap **12**. As shown in FIGS. **2** and **3**, cylinder cap **12** and cylindrical member **21** are fastened to one another by a plurality of bolts **24**.

Referring to FIGS. **1** and **2**, a plurality of heaters **25** extend radially from cylinder cap **12**. Each heater **25** comprises an outer tube element **251** and an inner tube element **252**. One end portion of outer tube element **251** is fixed to cylinder cap **12** and its other, outer end is closed. Outer tube element **251** communicates with the interior of inner tube element **252** and a hollow space **121** formed in cylinder cap **12**. Hollow space **121** is connected to the regenerating space R through an opening **121***a*. Therefore, the interior of outer tube element **251** communicates with the space R of regenerator **30** through hollow space **121** and opening **121***a*. Also, one end portion of inner tube element **252** is fixed to cylinder **12** and opens to the interior of cylinder **12**. Inner tube element **252** extends through hollow space **121** and the interior of outer tube element **251** with a small gap **31** to define passage-way for the medium gas.

A plurality of coolers **26** extend radially from connecting member **22**. Coolers **26** project from the opposite side of the apparatus as heaters **25**, and are axially offset from heaters **25**. Each cooler **26** comprises an outer tube element **261** with plural fins **261***a* and an inner tube element **262**. One end of outer tube element **261** is closed, and its other end is open and fixed to connecting member **22** so that the interior of outer tube element **251** communicates with a hollow space **221** formed in connecting member **22**. Hollow space **221** is connected to the space R of regenerator **30** through an opening **221***a*, whereby the interior of outer tube element **261** communicates with the space R of regenerator **30** through hollow space **221** and opening **221***a*. Inner tube element **262** is attached to cylinder **11** and extends into the interior of outer tube element **261** and hollow space **221** with a gap **32** which defines a passage-way for the medium gas. Inner tube element **262** opens to the interior of cylinder **11** at the cold chamber **11***b*. Thus, heat chamber **11***a* and cold chamber **11***b* are connected with one another through heater **25**, hollow space **121**, regenerator space R, hollow space **221** and cooler **26**. Regenerator **30** includes wire cloth **33** disposed in space R and wound up on the outer peripheral surface of cylinder **12**. Wire cloth **33** is placed between heater **25** and cooler **26** to prevent unnecessary waste of the heat. During the passage of the medium gas from hot chamber **11***a* to cold chamber **116**, the gas which has been heated by heaters **25**, gives up heat in regenerator **30** before entering the cooler; and, when the gas flows back, it takes up the stored heat again prior to its entry into heaters **25**. In the embodiment illustrated in FIGS. **5** and **6**, additional wire cloth **33** is shown wound up on the outer peripheral surface of cylinder **11**.

When this apparatus supplies mechanical energy, the heat from a heat source **33** is transmitted to the gas which is enclosed in the apparatus as the working medium through heaters **25**. The heat left in the gas after expansion and after passing through regenerator **30** is absorbed by cooling air via coolers **26**. The outer peripheral surface of outer tube element **261** of coolers **26** is provides with a plurality of fins **261***a* to promote heat exchange with coolers **26**.

The cyclical thermal process by which the apparatus operates will be described with reference to FIGS. **1** and **8**. Referring to FIG. **8** power piston **15** is in its lowermost position, while displacer piston **14** is in its uppermost position. All the gas in the system thus has been forced into cold chamber **11***b*, which is at its largest volume. Power piston **15** thereafter moves upward to compress the gas in cold chamber **11***b*; and displacer piston **14** moves downward to force the compressed gas through cooler **26**, regenerator **30**, heater **25** and into hot chamber **11***a*. When power piston **15** is in its uppermost position and displacer piston **14** has moved to a lower position wherein the volume of cold chamber **11***b* is at a minimum, all the compressed gas is in hot chamber **11***a*. The heat from heaters **25** causes the gas in hot chamber **11***a* to expand, and both power piston **15** and displacer piston **14** move downward to their lowest positions. While power piston **15** remains in its lowermost position, displacer piston **14** moves upward and pushes the gas from hot chamber **11***a*. During its passage from hot chamber **11***a* to cold water chamber **11***b*, the gas gives up a large part of its heat to regenerator **30** and its remaining heat to coolers **26**. FIG. **1** illustrates displacer piston in its intermediate stage of pushing the gas into cold chamber **11***b*, prior to reaching its uppermost position shown in FIG. **8** wherein all gas has been forced into cold chamber **11***b*. The cycles of operation thereafter are repeated, with the cool gas passing from cold chamber **11***b* to hot chamber **11***a* recovering heat from regenerator **30**.

A forced air convection type heater **100** is shown in FIGS. **7** and **8**, which utilizes a hot gas reciprocating apparatus, as illustrated in FIGS. **1–4**. In the hot gas reciprocating apparatus contained in heater **100**, similar parts are represented by the same reference numbers as in the embodiment shown in FIGS. **1–4**. Heater **100** includes a blow duct **110** provided with a cold air intake opening **111** and a warm air supply opening **112**, and a combustion apparatus or pipe **120** which supplies heat.

Blow duct **110** includes an outer duct element **110***a*, which is formed integral with an outer casing of heater **100**, and an inner duct element **110***b* which divides the blow duct space C from heating space H in which combustion apparatus **120** is placed. An opening **113** is formed in a midway portion of inner duct element **110***b* to take in warm air from heating space H. The hot gas reciprocating apparatus **1** is disposed within blow duct **110**. A blast fan **34** which is fixed on the outer terminal end of drive shaft **16** of apparatus **1**, is placed in air intake opening **111** to draw in cold air from outside of heater **100** into blow duct **110**. A main portion of apparatus **1**, including coolers **26**, is located in the blow duct and is thus exposed to the incoming cold air. The cold air thus flows into blow duct **110** due to operation of blast fan **34**, and while passing through duct **110**, cools the outer surface of apparatus **1** and effects heat exchange with the gas contained in the apparatus through coolers 26. During flow of the cold air toward warm air supply opening 112, it mixes with hot air supplied from heating space H through opening 113. The upper end portion of apparatus 1 extends into the heating space, and heaters 25 extend over the upper portion of combustion pipe 120 with a gap between them. Heaters 25 also extend through the area of the hot air passage-way which comprises opening 113. Therefore, heaters 25 of apparatus 1 are heated by combustion pipe 120.

In this construction of heater 100, when the gas enclosed in hot gas reciprocating apparatus 1 is heated by combustion pipe 120 through heaters 25, the heat left in the gas after expansion and after passing through regenerator 30 is absorbed by the cooling supplied by fan 34 via cooler 26. Apparatus 1 operates by the cyclical thermal process described previously with reference to FIGS. 1 and 8. Also, fan 34, which fixed on the outer terminal end of drive shaft 16, is rotated due to reciprocation of power piston 15 and displacer piston 14 through crank shaft 16.

As the result of the rotation of fan 34, cool air is taken into blow duct 110 through air intake opening 111 and during its flow toward warm air supply opening 112 cools cooler 26. Warm air flows into duct 110 from heating space H through opening 113 and mixes with the cool air. The cool air is thus warmed by the warm air and supplied to a room or rooms through opening 112.

As mentioned above, in this forced convector heater, the fan which causes the air flow within the heater is driven by the hot gas reciprocating apparatus, and most of the hot gas reciprocating apparatus is disposed in the blow duct. Only the heater of the reciprocating apparatus extends over the upper portion of the combustion apparatus, and is separated from the blow duct. Therefore, the temperature difference between the heater and the cooler of the reciprocating apparatus is securely established, to thereby ensure the high efficiency of the reciprocating apparatus.

This invention has been described in detailed in connection with the preferred embodiments, but these are examples only and this invention is not restricted thereto. It will be easily understood by those skilled in the art that other variations and modifications can be easily made within the scope of this invention.

We claim:

1. In a hot gas reciprocating apparatus including a cylinder having a cylinder cap, a power piston and a displacer piston both slidably carried within said cylinder, said displacer piston dividing the interior of said cylinder into two chambers one of which is located between said power piston and displacer piston, said two chambers being connected to one another through cooler means for cooling a fluid in said apparatus, a regenerator and heater means for heating a fluid in said apparatus, the improvement comprising said heater means extending radially from a side surface of said cylinder, said cooler means extending radially from an opposite side surface of said cylinder, and said heater means being axially spaced along said cyclinder from said cooler means.

2. The hot gas reciprocating apparatus of claim 1 wherein said heater means comprises a plurality of heaters each of which includes an outer tube element and an inner tube element disposed within an interior of said outer tube element with a gap between the tube elements to define a fluid passage-way.

3. The hot gas reciprocating apparatus of claim 2 wherein said cooler means comprises a plurality of coolers each of which includes an outer tube element with a plurality of fins to promote heat exchange and an inner tube element extending into an interior of said outer tube element with a gap between the tube elements to define a fluid passage-way.

4. The hot gas reciprocating apparatus of claim 1 wherein said regenerator is defined between an outer surface of said cylinder and an outer annular member which is disposed around the outer peripheral surface of said cylinder with a gap between said cylinder and said outer annular member, and a regenerative metal disposed in said gap between said cylinder and said outer annular member.

5. The hot gas reciprocating apparatus of claim 4 wherein said regenerative metal comprises a wire cloth.

6. In a forced convector heater including a blow duct having a cold air intake opening and a warm air supply opening, and the blow duct dividing a passage for cold air from a heating space, a combustion apparatus disposed in the heating space and a blower fan disposed in said cold air intake opening, the improvement comprising a hot gas reciprocating apparatus disposed in said blow duct and said fan fixed on outer terminal end of a crankshaft of said apparatus, said hot gas reciprocating apparatus having a heater means for heating fluid in said apparatus and a cooler means for cooling fluid in said apparatus, and said heater means projecting radially from said hot gas reciprocating apparatus to extend adjacent an upper portion of said combustion apparatus.

7. The forced convector type heater of claim 6 wherein said cooler means of said hot gas reciprocating apparatus is exposed in said blow duct.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,578,949

DATED : April 1, 1986

INVENTOR(S) : Yuji Takei and Naotsugu Ishiki

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2, line 58, change "15" to --16--.

Signed and Sealed this

Eighth **Day of** *July 1986*

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer *Commissioner of Patents and Trademarks*